

Quantifying Acoustic Uncertainty Due to Marine Mammals and Fish Near the Shelfbreak Front off Cape Hatteras

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LONG TERM GOALS

The long term goals of our work on acoustic uncertainty due to fish and marine mammals are to: 1) understand the nature of low-to-medium frequency (100-2000 Hz) acoustic scattering (specifically reverberation and attenuation) by fish schools and larger marine mammals, 2) advance our acoustic methods of quantitatively imaging fish schools and tracking vocalizing marine mammals, and 3) understand the correlation between the detailed physical oceanography and the biology and acoustics.

OBJECTIVES

Our primary objectives this year were: 1) complete analysis of our “year one” survey cruise data and especially our “year two” major experiment data (taken off Cape Hatteras, N.C. to measure the acoustics, biology, and physical oceanography of fish schools) and 2) begin publishing our results.

APPROACH

The basic tools/methodology employed in our “year two” major cruise consisted of a combination of: 1) an AUV mounted acoustic source, 2) moored multi-element SHRU acoustic receiver arrays, 3) a

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shipboard acoustic resonator, 4) fish-attraction devices (FAD's), 5) a three-AUV fish-field mapping effort (employing sidescan sonar plus optics) and 6) ScanFish, ADCP, and moored sensor oceanographic field mapping. The day-to-day experimental plan was to: 1) survey the oceanography at night to find the shelfbreak front and other features that might attract fish, 2) survey for fish during the day based on the oceanography survey results, 3) given a good fish population "target", deploy the SHRU receivers and FAD's and perform REMUS vehicle operations to both map the fish school and examine its 500-2000 Hz scattering characteristics.

Our post cruise (year4) approach is simply to simultaneously analyze the acoustic, biologic, and physical oceanographic data to see the correlations between the three areas.

WORK COMPLETED/ACCOMPLISHMENTS

A suite of signal processing programs was developed over the past two years to allow data extraction from the SHRU recorders, matched filter processing, pulse compression and frequency analysis. These programs were used this year to analyze the 2012 acoustic data, and we now have results that show the attenuation from the fish and the scattering from the medium and direct arrivals that competes with scattering from the fish. We are now in the process of producing a peer-reviewed manuscript on these acoustics results.

RESULTS

The acoustic model has been further refined in this year. To obtain a better estimate of source positions, the navigation data of the source AUV (Snoopy) was been corrected using the GPS fix obtained when the AUV surfaced. The estimated positions of the source AUV were verified by comparing its surveyed topographic map to another independent map obtained from the second AUV (Edgar) equipped with an inertial navigation system. Both of the topographic maps show a 6-m deep scour at the ship wreck site, along with other seafloor features consistently observed by both AUVs (see Figure 1). With the improved source position estimates, numerical acoustic models of eigenrays and broadband arrival patterns were constructed using a time series of water column sound speed profiles measured in the experiment area. The eigenray tracing shows some, but not significant, scattering from the scour (see Figure 2). The simulated arrivals from a high-order broadband PE model agree with the data very well in terms of the arrival time and pulse spread durations (see Figure 3). Because the numerical model does not yet have sea surface roughness scattering (which was appreciable) and fish school scattering (which probably was not, due to the dispersal of the school), some discrepancy of the scattering pattern is observed between the data and the model.

During the field operations in May, 2012, oceanographic conditions were unusual with warm Cold Pool temperatures. The normal 4-5 Deg. C temperature difference between waters of the continental shelf and slope (across the shelfbreak front) was not present. Comparison with data from the same location and same time of year in 1996 indicated a 4.75 Deg. C depth averaged anomalous warm temperature in May, 2012. In order to investigate this anomaly, Gawarkiewicz and his post-doc Ke Chen examined NDBC buoy surface temperatures from a series of buoys between the Gulf of Maine and the mouth of Chesapeake Bay. The buoys showed warm anomalies ranging from 1.7 to 2.6 Deg C over the first six months of 2012 (Fig. 4). Further analysis of satellite derived sea surface temperature anomalies showed that this warm anomaly extended from the Gulf of Maine down to Cape Hatteras throughout the entire continental shelf region.

In order to investigate what caused this anomaly we examined air-sea flux products and were able to determine that a reduction in warming in the winter of 2011-2012 caused the warm conditions in the spring of 2012 (Chen et al., 2014). The large spatial extent of the warming and its long duration undoubtedly played a role in the absence of butterfish and bluefish from our study area in a time period when they were expected to be present in great abundance. The warming in 2012 had extensive impacts in the northeast and we are continuing to examine the data collected in both 2011 and 2012 to examine impacts of this warming on the structure of the shelfbreak front.

IMPACT/APPLICATIONS

The impact of our experiment should be: 1) an increased understanding of the scattering of sound through fish schools, which can help discriminate fish schools as “false targets” for sonars, 2) improved methods for mapping fish populations and schools, which is important in that the “biological field” is often an unknown for both experimental studies and Navy applications, and thus could be quantified, and 3) a beginning understanding of how climate change may be affecting shallow water acoustics, both through the fish, and perhaps more importantly, through the ocean temperature field.

TRANSITIONS

Being able to model the acoustics of fish schools will allow them to be discriminated against as false targets ion sonar systems. Also, in the case of larger shoals, the effective attenuation due to the fish can be estimated. Further, the ability to incorporate fish and climate change into Navy models could be a useful payoff.

RELATED PROJECTS

This work is related to the work of K. Benoit-Bird and her work off the west coast of the United States as well as T. Stanton and D. Greenbaum who are working on theoretical aspects of fish school behavior and the scattering of sound within fish schools. This work also relates to efforts to quantify uncertainty in acoustic propagation from the Quantifying, Predicting, and Exploiting Uncertainty DRI.

PUBLICATIONS

A. Recent Publications (refereed)

Chen, K., G. G. Gawarkiewicz, S. J. Lentz, and J. M. Bane (2014), Diagnosing the warming of the Northeastern U.S. Coastal Ocean in 2012: A linkage between the atmospheric jet stream variability and ocean response, *J. Geophys. Res. Oceans*, 119, doi :10.1002/2013JC009393.

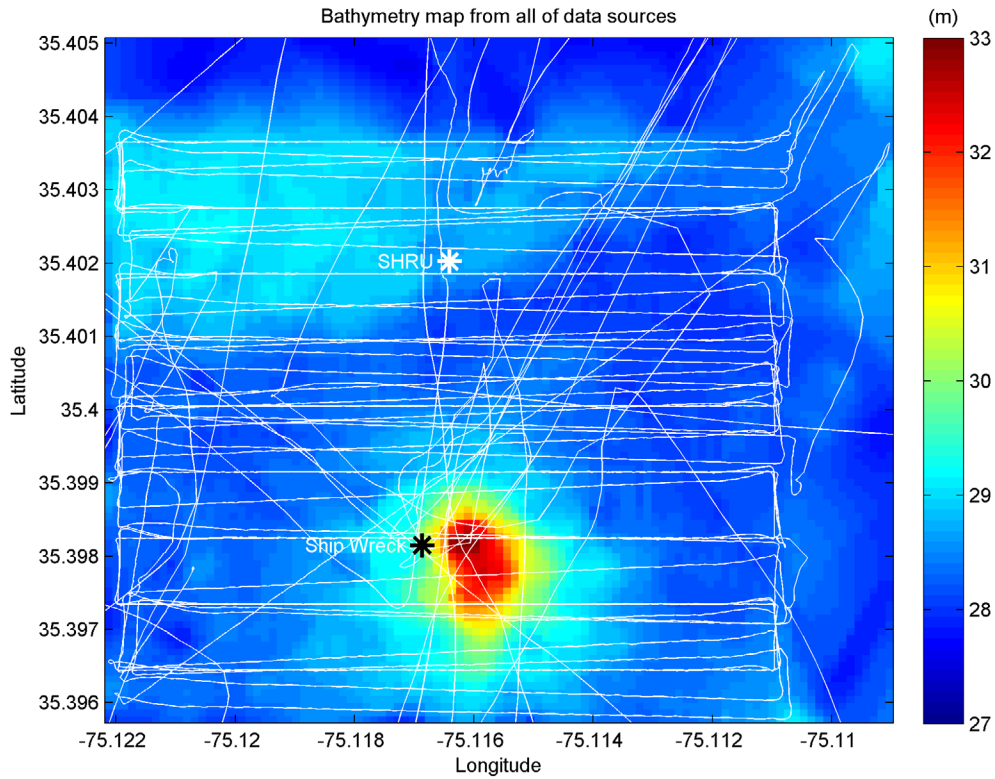


Figure 1. Bathymetric map created using all data sources. Scour pit near shipwreck is a prominent feature.

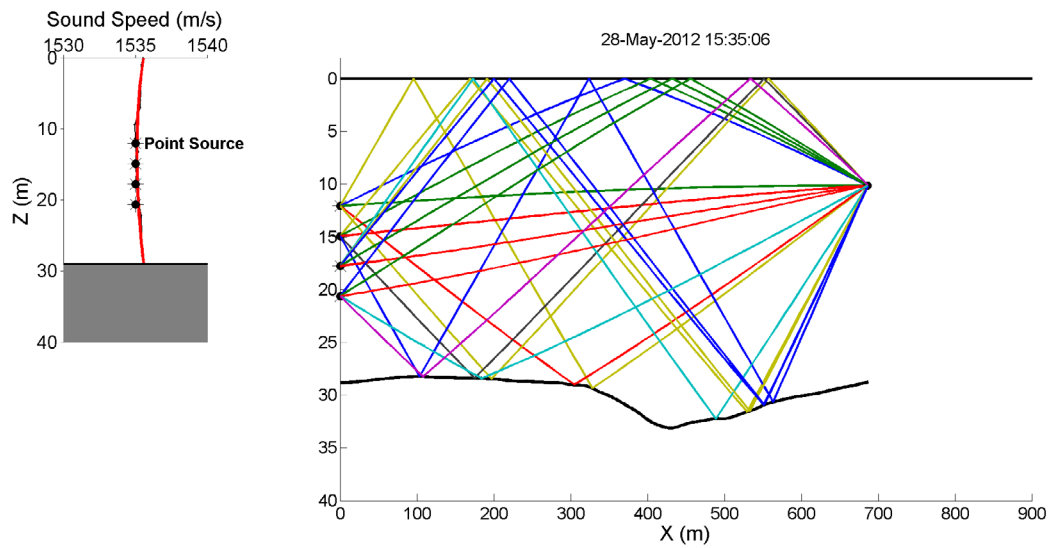


Figure 2. Soundspeed profile and eigenrays for a typical source to receiver range and azimuth.

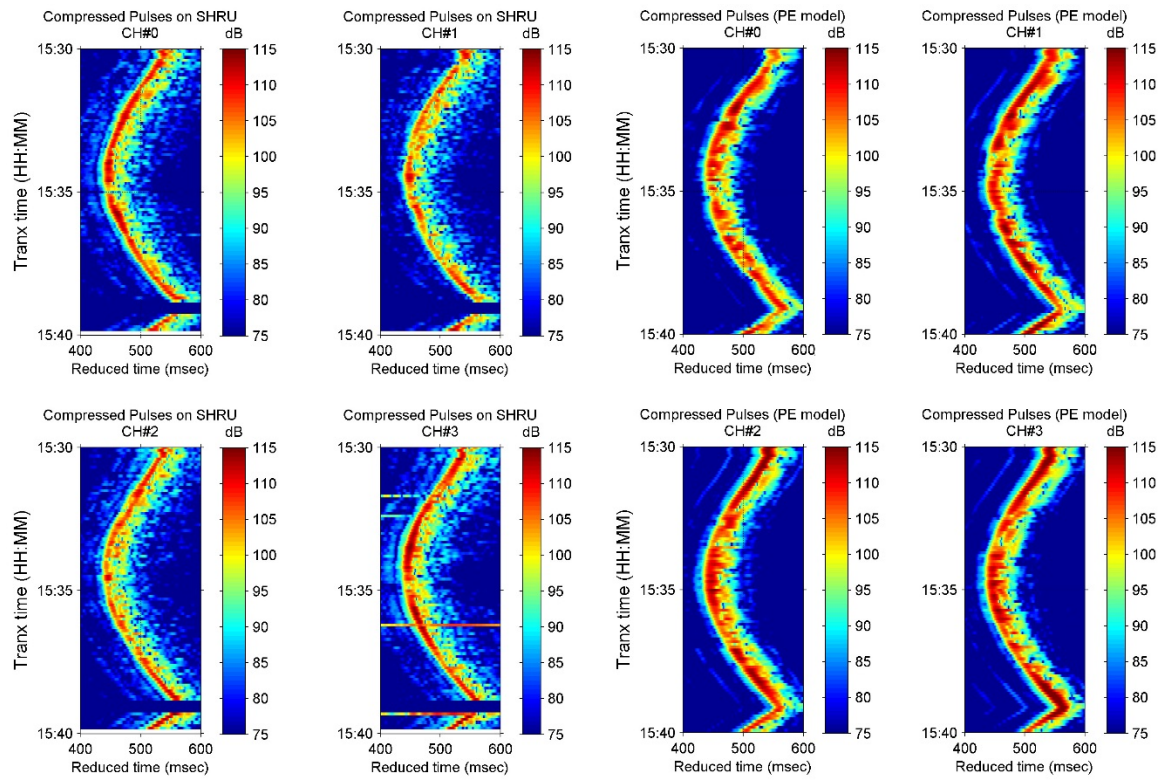
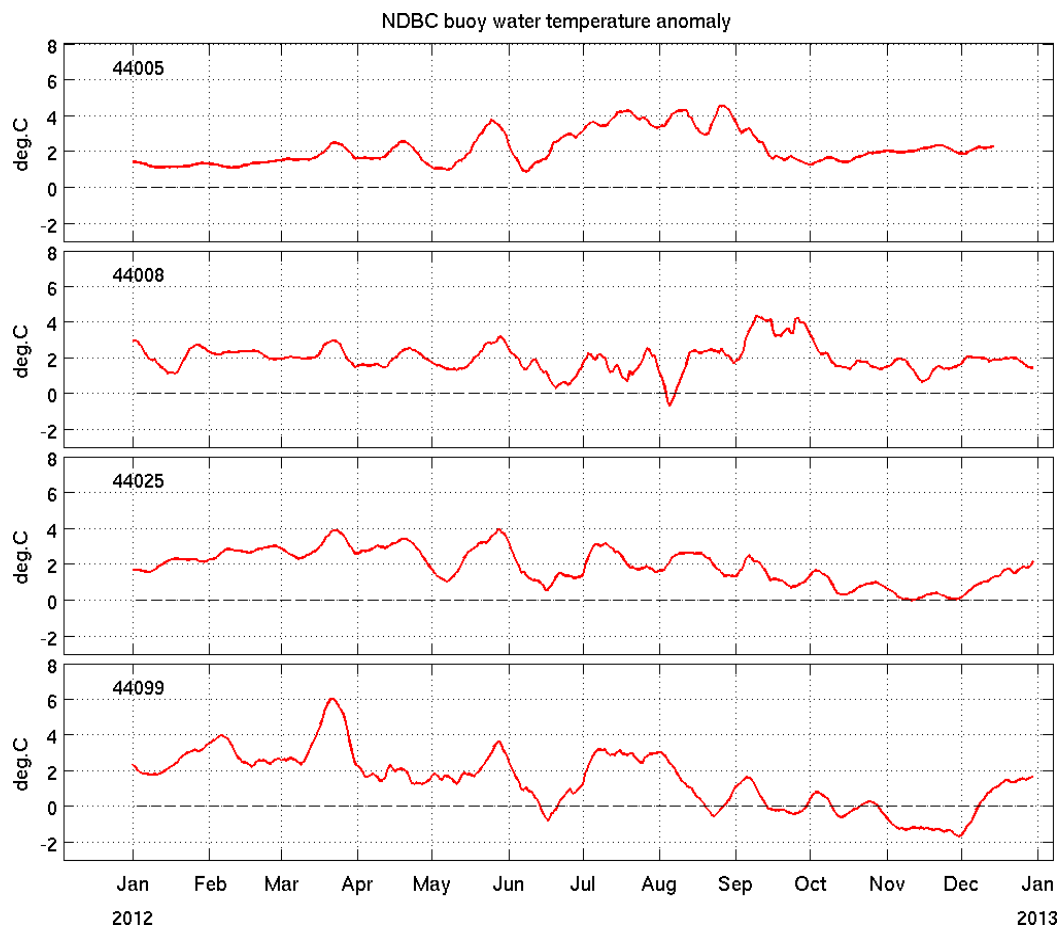


Figure 3. Arrival pattern, showing spread due to bathymetric scattering.



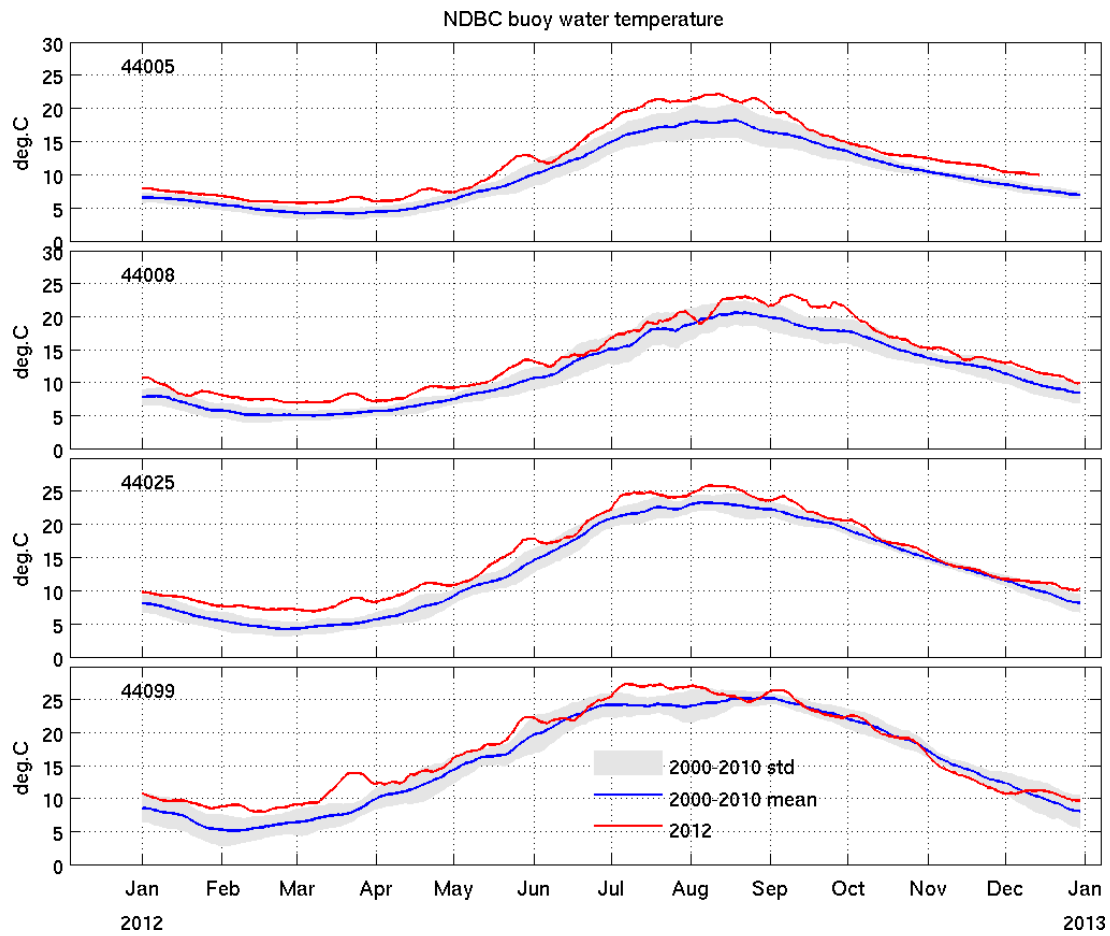


Figure 4 Time series of near surface temperatures from NDBC buoys from the Gulf of Maine (top panels) down to the mouth of Chesapeake Bay (bottom panels). The first plot is the anomaly versus the ten year average from 2000-2010 from the same buoys. The second plot shows the values through 2012 with the ten year mean and standard deviations plotted.